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4. He is a splendid example of mental causation, as against metaphysical Free Will, and, for his business functions, a marvelously efficient bodily and mental human machine.
5. His better mental traits of activity, success, some sympathy, and a deal of optimistic good cheer are his more natural characteristics by instinct, except that the optimism and good nature are increased by business life; while his lower traits of an exhausting high-pressure activity, absorption in beating, selfishness, suspicion, and a narrowness of intellectual and aesthetic interests, are chiefly developed by the competition struggle of business life.

November, 1905.

[*Paper M.*]

# GLACIAL AND MODIFIED DRIFT OF THE MISSISSIPPI VALLEY FROM LAKE ITASCA TO LAKE PEPIN.

By Warren Upham.

From its source in lake Itasca to Minneapolis and St. Paul, the Mississippi river traverses a large area of the late glacial drift, with many marginal moraines, belonging to the Wisconsin stage of the Ice age. In the outermost moraine belt, intersected by this river within a few miles south of St. Paul, several moraines are merged together, namely, the Altamont, Gary, Antelope, Kiester, and Elysian moraines, or the first to the fifth in the series of twelve which are traced in well defined separate courses across the west half of Minnesota. Continuing eastward through the central and eastern parts of this state, these twelve moraines have an equally conspicuous development, in belts of irregularly knolly and hilly drift, partly till and partly modified drift, rising usually to heights of 50 to 150 feet above the smoother intervening drift tracts; but two or more consecutive moraines are in many places pushed together in the vicinity of the Mississippi river and farther east, or are interlocked as a network, so that the series mapped there can only be provisionally identified with the

twelve distinct and successive moraines mapped west and north of this part of the Mississippi.

Above the junction of the Minnesota river, the upper Mississippi passes through six moraines formed later than those noted as confluent close south and east of St. Paul, these of later dates being the Waconia, Dovre, Fergus Falls, Leaf Hills, Itasca, and Mesabi moraines, which in this order are the sixth to the eleventh of the Minnesota series. Only one, the last and most northern recognized in the state, named the Vermilion or twelfth moraine, runs through northern Minnesota beyond the Mississippi watershed.

Details of the course, topographic features, material and structure, and the chronologic sequence, of these most prominent drift deposits of our region, have been published throughout the many chapters describing our counties in the final reports of the Minnesota geological survey. Little attention was given there, however, to the very interesting question of the probable length of time, in years and centuries or in thousands of years, occupied by the accumulation of this numerous series of frontal moraines, marking short or long pauses, or sometimes re-advances, of the ice border during its general wane and departure from the state area.

But in another work, for the United States Geological Survey, on the Glacial Lake Agassiz, I have shown reasons for ascribing to the entire history of that vast ice-dammed lake, stretching gradually about seven hundred miles from south to north in the valley of the Red river and the basin of lake Winnipeg, no longer time than one thousand years. This is a proportional estimate, in connection with the evidence set forth by N. H. Winchell, G. F. Wright, and other glacialists, both in America and Europe, including the present writer, that the Postglacial period, since the recession of the ice-sheets from the northern United States and Canada and from northwestern Europe, measures about 10,000 to 5,000 years, being approximately alike on opposite sides of the Atlantic.

In comparison with these estimates, the time required for the formation of any one of our great marginal moraines could be no more than a few decades. All the retreat of the ice-sheet on the moraine-bearing region of Minnesota, from the compound belt of marginal drift hills adjoining St. Paul to the Itasca, Mesabi and Vermilion moraines, at and beyond the

most northern sources of the Mississippi, did not probably occupy more than ten or fifteen centuries. If the recession of a Mississippi cataract from the site of Fort Snelling northward, now called the Falls of St. Anthony, began only about 8,000 years ago, as shown by Winchell, the latest melting of the icefields on our northern boundary took place within some one thousand or fifteen hundred years afterward, that is, between 7,000 and 6,000 years ago.

Far greater age, however, must be attributed to the glacial drift of a tract 40 to 50 miles wide in southeastern Minnesota, lying next east of the outer moraines, which run southerly from St. Paul through the west part of Dakota county, and through Rice, Steele, and Freeborn counties, into Iowa. The tract of more ancient drift comprises much or all of Dakota, Goodhue, Wabasha, Dodge, Olmsted, Mower, and Fillmore counties, lying between the Altamont or first moraine and a large driftless area, which includes a width of 20 to 40 miles in the southeast edge of this state from lake Pepin southward, between the attenuated margin of the glacial drift and the Mississippi river. The same remarkable driftless area reaches thence nearly 100 miles east in Wisconsin, but has its greatest extent of about 150 miles from north to south, continuing, mainly east of the Mississippi, to the northwest corner of Illinois.

In the series of stages or epochs of the glacial period, characterized by alternating growth and wane of the continental ice-sheet, with advance, retreat and re-advance of its borders, ascertained by Chamberlin, Salisbury, Leverett, Calvin, and others, our tract of the old drift outside the moraines in the southeast part of Minnesota belongs probably to the Kansan stage of glaciation, when the ice-sheet attained its greatest extension in the center of the continent, probably fifteen or twenty times as long ago as the final departure of the ice from this state.

The great age of this drift is indicated in Dakota and Goodhue counties, bordering the Mississippi from St. Paul to lake Pepin, by occasional columnar or towerlike remnants of the St. Peter sandstone, of which the most noteworthy are Castle rock, about a mile east of the railway station of that name and Chimney rock, in the east edge of the northeast quarter of section 31, Marshan, about eight miles south of

Hastings. Castle rock originally had a height of 70 feet above the lowest ground at its base, and its upper 20 feet was a slender rock column, which, by the effect of subaerial erosion of its lower part, fell down several years ago. The Chimney rock here mentioned, one of several in Dakota county bearing this name, is the most picturesque and perfect example of columnar rock weathering in Minnesota, or indeed, as I believe, in our entire country. It is a vertical pillar, measuring 34 feet in height and about 6 and twelve feet in its less and greater diameters, being no thicker near the base than in its upper part. Plate VIII gives a view of this sandstone column, of which no former description or illustration has been published.

Such spires of easily crumbling sandstone could not endure the envelopment of this area by the slowly moving ice-sheet, which is known to have once existed there by the continuation of the very old drift many miles beyond these rock pillars. During the deposition of that glacial drift, knolls or small plateaus of the sandstone, capped by an exceptionally hard layer or by the next higher Trenton limestone, and having sufficient area to withstand the pressure of the ice current, doubtless occupied the sites of the Castle and Chimney rocks; and by subsequent erosion of weathering, through the agencies of rain and wind, cold and heat, the sandstone slowly crumbled away, leaving only these columnar masses. How long a time would be required for this result, we can only vaguely conjecture; but it seems probable that the 50,000 or 100,000 years which have been variously computed to have passed since the culmination of North American glaciation, in the Kansas stage, would suffice. It is evident that the relatively short time since the Illinoian and Iowan stages of glaciation would be inadequate.

The Ice age thus was very long in comparison with the Postglacial period. Indeed, the whole Quaternary era may have measured 150,000 years, or more, in which time were comprised the gradual oncoming of the ice-sheet, its repeated fluctuations, and at last its most energetic accumulation of marginal morainic hills, whenever its final melting and retreat were temporarily interrupted.

With the departure of the ice-sheet, while it was being melted back from one marginal moraine to another, yielding its ground in general by a recession from south to north, the

Mississippi valley was partly filled with modified drift, or the stratified gravel, sand, and fine silt, which form terraces or plains on either side of the river. An abundant supply of water from the dissolving ice and from rains caused the river to be in a continual flood stage during the summers; and much of the drift was then carried into the valleys of the great river and its tributaries, filling them from side to side up to the levels of their highest gravel and sand terraces. In proportion as the ice-sheet withdrew from this area, the tribute of drift borne into the valleys was greatly diminished, while yet the Minnesota and St. Croix rivers, and the Mississippi below their mouths, were flooded through every summer by the outflow of lake Agassiz and of the Western Superior glacial lake, both held by the barrier of the retreating ice-sheet farther north. Then the valley floodplains so lately formed were deeply channeled until the Mississippi flowed at levels 50 to 100 feet lower than now along some parts of its course in and adjoining Minnesota.

After the great discharge of the glacial lakes ceased, the ability of these rivers to erode their valleys was less, and in consequence the alluvium of tributaries has in some cases partly refilled the main valley. Thus the silt brought to the Mississippi by the Chippewa river during the Postglacial period has been spread as a barrier at its mouth and southward, forming lake Pepin, 25 miles long and 1 to 3 miles wide, which has a maximum depth of 56 feet in its southern part. The Mississippi valley for many miles below the lake has been refilled with the Chippewa alluvium nearly to that depth. In the same way lake St. Croix, 25 feet deep, has been formed in the St. Croix valley just above its mouth, by the barrier of the Mississippi alluvium; and likewise the shallower Lac qui Parle, on the Minnesota river, owes its existence to refilling of the Minnesota valley by the silt of the Lac qui Parle river.

In the city of St. Paul a very coarse valley deposit, allied with the modified drift, but consisting mainly of small and large fragments and blocks of the underlying Trenton limestone, is spread here and there on the level Trenton terrace plain, about 90 to 120 feet above the Mississippi and also about 100 feet below the tops of the valley bluffs. The coarse limestone debris, occasionally holding blocks of all sizes up to 20 or 30 feet in length or diameter, is seen in many places, but

not continuously, along the distance of seven miles from the vicinity of Fort Snelling to the east part of the city, varying from a few feet to about 30 feet in thickness. With its commonly more or less waterworn masses derived from the Trenton limestone, which makes up nine-tenths or often nineteen-twentieths of the deposit, are everywhere scanty drift pebbles and less frequent boulders, brought from great distances at the north, which show for this unusual deposit an intimate relationship with the glacial and modified drift. It is nowhere overlain by till, nor by valley drift of the usual type. No description of this singular formation, illustrated in Plate IX, has been previously published.

Guided by helpful suggestions of Prof. C. W. Hall and Dr. F. W. Sardeson, I am led to ascribe this very coarse valley debris to erosion by the river at some time during the final recession of the ice-sheet, when the ordinary modified drift, continues with the wide floodplains of the Mississippi at Minneapolis, Fort Snelling, South St. Paul, Newport, and Langdon, had filled the valley just to the height of this limestone terrace. It is needful, however, to go back to a much earlier part of the Glacial period and thence bring forward a very important part of this explanation.

During some long interglacial stage, probably the Buchanan time of glacial recession next after the Kansas glaciation, southern Minnesota had been uncovered from the ice and the Mississippi here had sculptured its valley to nearly its present form, allowing prolonged erosion by rivulets and by weathering on this limestone tract, which reaches seven miles along the valley from southwest to northeast. This part of the valley, it should be noted, lies transverse to its general course both above and below; and it is also transverse to the directions of the glacial currents during both the earlier and later advances of the ice-sheet. Parts of the limestone surface became very irregularly channeled and decayed during this interglacial exposure of perhaps 15,000 years, as its duration is computed by Prof. N. H. Winchell from an interglacial drift-filled gorge of the Mississippi in the west part of Minneapolis. Afterward the valley here and nearly all of southern Minnesota were again covered by the readvancing ice-sheet during the Illinoian and Iowan glaciation, and were next uncovered, as I think, during the Wisconsin stage of the final

departure of the ice. Then the river built up its floodplain of modified drift to a height that coincided closely with that of the limestone terrace, causing the mighty stream to flow there in rapids, carrying the limestone masses and finer debris short distances from their original beds, and in some places undermining and toppling down the very large limestone blocks.

This peculiar formation is well seen near the north end of the High Bridge, for a third of a mile thence westward, at numerous other places on that northeast side of the river through this city, and on the opposite side near the Edison school in West St. Paul. It is of very unusual and surprising character and aspect, quite unlike any other formation which I have ever found in much exploration of glacial and valley drift. Therefore the probable conditions of its origin have been sought, with the results here presented, and with the hope that other Minnesota students of glacial geology will more fully investigate the many interesting questions connected with the history of this valley during the Ice age.

December 5, 1905.

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[*Paper N.*]

# METEOROLOGICAL STATISTICS.

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By William Cheney and T. S. Outram.

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These statistics are a continuation of the personal Meteorological Observations began in 1864 by William Cheney, for many years a member of this Academy. The first table published by the Academy is in Bulletins vol. I, 1873-1879 pp. 174-186; the second in Bulletins vol. II, 1880-1882, pp. 422-435; the third, this volume, ante, pp. 123-130.